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Vibration control of wind turbine by using active mass damper equipped with a magnetic fluid

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ABSTRACT: Today, due to the importance of the environment, the use of renewable energy-generating structures has received more attention. Therefore, dynamic analysis of such structures under natural hazards, especially earthquakes, is important. One of these structures is the wind turbine. In this article, its vibration is controlled by an active mass damper equipped with a magnetic fluid damper. The mass values used for tuned mass dampers are equal to 10, 20, 40 and 60 tons. In addition, two types of MR dampers are considered. Dynamic analysis of the wind turbine subjected to different earthquakes is studied and appropriate evaluation indexes are defined. The performance of the active mass dampers is compared according to the evaluation indexes and the optimal active damper is introduced. In this article, a 5MW wind turbine constructed by the National Energy Laboratory Renewable is considered. the multi-degree freedom model structure used for this wind turbine is linear. The wind turbine is subjected to near and far field earthquakes in an out-of-plane direction, then its vibration is mitigated by using the proposed active mass dampers. Finally, the results show a significant reduction in displacement and velocity of the wind turbine tower which is equipped with the optimal active mass damper.

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1- Introduction

One of the devices that can be used to generate renewable energy is wind turbine structure. Since onshore wind turbines are more widely used in Iran, this model of wind turbine is discussed in this study. Wind turbine modeling is possible in various methods, the simplest method is single-degree freedom [1, 2]. Another method is multi-degree freedom [3, 4], which is more accurate than the single-degree free model and because the blade stiffness in the out-of-plane direction is less than in-plane direction, the possibility of damage in the out-of-plane is more than in-plane direction. so the wind turbine vibration in the out-of-plane direction has attracted more researchers' attention [5, 6]. In order to control the vibration of wind turbine, various researches have been done and generally devices are divided into three general categories of active, passive and semi-active control devices [7]. The wind turbine is subjected to conventional loads and the amplitude of vibrations should remain in the linear range. it is also important to note that the nonlinearity of this structure causes structural damage.In this study active mass damper is added to wind turbine which causes reduction in the amplitude of vibrations and ensures that wind turbine has linear behavior. The active mass damper is made of a passive mass damper with a magnetic fluid damper and also, the focus of this paper is on controlling the vibration of wind turbines just caused by earthquakes.

2- Methodology

A multi-degree freedom model is used for wind turbine [4], which consist of 8 degrees of freedom. Degrees of freedom from 1 to 3 related to the edgewise displacement of the blades, degrees of freedom from 4 to 6 related to the flap-wise displacement of the blades and degrees of freedom 7 and 8 related to fore-aft and side-side displacement of the tower, respectively and a 5MW wind turbine is used for modeling [8]. Figure 1 shows the degrees of freedom.

The matrix equation of motion for the wind turbine is presented in equation (1) and (2). First Equation is for wind turbine without a mass damper. In the second equation, the wind turbine is equipped with a mass damper.

$$M\ddot{\tilde{q}}+C\dot{\tilde{q}}+K\tilde{q}=Q_{seismic} \tag{1}$$

$$M\ddot{\tilde{q}}+C\dot{\tilde{q}}+K\tilde{q}=Q_{seismic} \tag{2}$$

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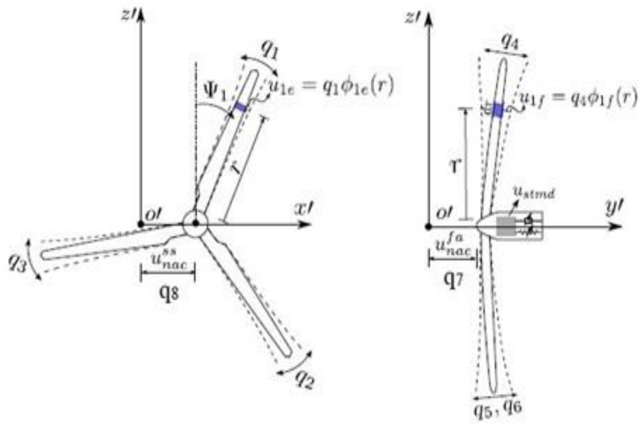

Fig. 1. Degrees of freedom [4]

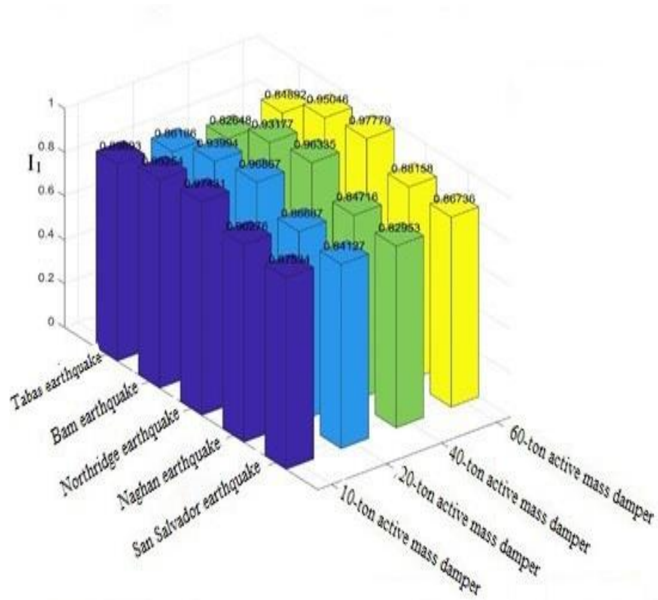

Fig. 2. Displacement index values of the wind turbine tower equipped with the second active mass damper

In these two equations M, C, K and $Q_{seismic}$ represent in order Mass matrix, Damping matrix, stiffness matrix and Earthquake vector.

Due to the ease of modeling, the wind turbine is assumed to be off. This modeling is done by MATLAB and Simulink software. In this wind turbine, 2 magnetic dampers are utilized along with mass damper in order to make active mass dampers. The first MR damper is made in 2002 [9] and the second one in 2011 [10], mass damper is used with different masses of 10, 20, 40 and 60 tons which are equivalent to 1.5%, 3%, 6% and 9% of the structure weight, respectively. The seismic force is considered in out of plane direction.

3- Results and Discussion

To compare these two magnetic dampers the currency is set to 2 Amps. Three particular indexes are introduced to evaluate the performance of dampers under earthquakes. The first index is the ratio of the maximum displacement of the wind turbine equipped with a damper to the maximum displacement of a wind turbine without a damper. This is also the most important index, because the base shear of the wind turbine is determined by this index. The second and third indexes respectively are the ratio of maximum velocity and maximum acceleration of wind turbine equipped with a damper to maximum velocity and acceleration of wind turbine without a damper. In order to control the vibration of this wind turbine under near and far field earthquakes, the active mass damper is put on the top of the tower beside the nacelle.

3- 1- Displacement index

Except for Tabas earthquake, the results show that the displacement index for the first damper has decreased with the increase of the tuned mass in the majority of the near-field earthquakes, but the displacement index for second damper has decreased in all near-field earthquakes; and in both cases, the 20-ton mass damper has the same performance as the 40-ton mass damper. In far-field earthquakes, the second active damper works better than the first active damper. Therefore, based on this index, the performance of the first active damper is better than the second one. Figure 2 shows the displacement index of the wind turbine tower equipped with the second active mass damper which is subjected to near-field earthquakes.

3- 2- Velocity index

The velocity index in most near-field earthquakes for the first damper is less than the second damper. But in most far-field earthquakes the second damper has shown better performance. The active first damper has not performed well in the velocity index and by increasing the mass of the dampers in far-field earthquakes, the velocity index increases too.

3- 3- Acceleration index

The acceleration index in near-field and far-field earthquakes doesn't differ in both 10 and 20-ton active mass dampers, but if the mass increases, the performance of the first damper gets better than the second one. Therefore, based on the acceleration index, both active dampers have shown almost the same performance.

4- Conclusions

In this study, active and passive mass dampers are compared with each other. The results show that the proposed active dampers performed better than the passive dampers. The used dampers have masses equal to 1.5%, 3%, 6% and 9% of the mass of the structure and the damper with a mass equal to 3% of the mass of the structure is more efficient than the other dampers. Among active dampers, the second MR damper has shown better performance in far-field earthquakes, but the performance of these two types of MR dampers in near-field earthquakes has been very close to each other. Therefore, in total, the second active mass damper which has 20-ton masses is introduced as the optimal damper. Based on the results of this study, the following conclusion remarks can be obtained:

1. In case of near and far field earthquakes, by using the proposed optimal active mass damper, the displacement and velocity indexes are reduced.

2. By using the proposed optimal active mass damper, the dynamic behavior of the wind turbine in some earthquakes such as El Centro earthquake, is improved. however, in a number of earthquakes, it may increase the value of the acceleration index.

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